

## VII. HOSPITAL VOLUME AND CORONARY ARTERY BYPASS GRAFT SURGERY OUTCOMES

The association between the quantity of care that a physician or hospital provides and the quality of care that patients receive has been intensely investigated by clinicians and health services researchers. In the majority of the published data investigating this relationship, researchers have generally found that the higher the number of patients a physician or hospital treats with a specific condition, the better, on average, the patients' health outcomes. This "volume-outcome" relationship has been documented for a wide variety of medical conditions and surgical procedures at several levels of care, including the physician, clinical team, and hospital level. In a report reviewing the volume-outcome relationship, published by the Institute of Medicine (Hewitt, 2000), the author noted that 77% of the published volume-outcome studies demonstrate a significant relationship between higher physician and hospital volumes and better health outcomes. In fact, in this Institute of Medicine review, no studies were found to demonstrate a significant negative relationship between higher volumes and outcomes (i.e., resulted in worse health outcomes).

The volume-outcome relationship has been most extensively studied for patients receiving coronary artery bypass graft (CABG) surgery. This observed relationship could imply that regionalizing services, thereby increasing average physician and hospital volumes, would improve the quality of healthcare. Whereas most of these studies found that hospitals performing more CABG surgeries had better outcomes, the policy significance of this relationship remains controversial. Many question the magnitude of the CABG volume-outcome association since several recent studies using more robust statistical methods have failed to find a clinically significant relationship (Peterson, 2004; Shahian, 2001; Christiansen, 1997; Kalant, 2004; Panageas, 2003).

### CCMRP 2000-2002 Analyses

The following analyses and report examine the volume-outcome relationship in CABG surgery using the California CABG Mortality Reporting Program (CCMRP) data from 2000 to 2002. The primary goal of these analyses is to use the most current methodological techniques to determine whether hospitals performing more CABG surgeries have lower risk-adjusted mortality than hospitals performing fewer CABG surgeries in California.

First, a patient-level risk-adjusted mortality prediction model was developed using a hierarchical or multi-level technique. Hierarchical models (also referred to as multi-level models, random or mixed-effect models, and random coefficient/intercept regression models) are increasingly used in health services research to analyze multi-level data, particularly when analyses are done on patient data from many hospitals. These models are more appropriate than traditional patient-level models for making inferences at the hospital level because they adjust for the "clustering" of patients (Shahian, 2001; Christiansen, 1997; Leyland, 2003; Burgess, 2000). Specifically, it is known that patients are not randomly distributed among all hospitals and that similar patients are cared for at similar hospitals. These techniques adjust for non-randomly distributed, unmeasured characteristics that contribute to a patient's CABG mortality rate. All of these characteristics could contribute to a hospital's observed CABG mortality rate that may not be accounted for in a traditional patient-level logistic regression model. Not accounting for some of these factors, particularly patient-level factors, may cause a hospital's CABG mortality rate to appear better or worse than it should be. For example, if one hospital treats more patients from lower socioeconomic neighborhoods (a factor not accounted for in the mortality risk model but

known to be associated with CABG mortality), this so called “clustering” of such patients may increase the observed mortality rate of this hospital, thereby resulting in a higher than expected “observed-to-expected” (O/E) mortality ratio.

To demonstrate the validity and reliability of the hierarchical model, it was compared to the mortality prediction model developed using traditional logistic regression. Then, to assess the relationship between hospital CABG volume and mortality, annual hospital volume was first included as a continuous independent variable in both the traditional logistic regression and the hierarchical logistic regression models (using a random intercepts model). Second, to visualize the hospital volume-outcome relationship, the hierarchical model was used to plot the O/E ratio for each hospital against its annualized volume over the three years. Third, hospitals were grouped into volume categories depending upon the number of CABG procedures performed on average over the three years. Then, these categories were included as indicator variables in the hierarchical logistic regression to determine whether the different volume categories were significantly associated with higher or lower mortality.

## Results

The CCMRP CABG database contains detailed patient-level clinical data on 57,388 isolated CABG surgery procedures in 83 hospitals in California from 2000 to 2002.<sup>7</sup> The average annual hospital CABG volume was 251 cases, with a range among individual hospitals of 39 to 1,277. The overall inpatient mortality rate was 2.71%, and the average hospital mortality rate was 3.30%, with a range among individual hospitals of 0.86% to 12.12%. On average, mean predicted mortality rates were higher among low-volume hospitals than among high-volume hospitals, which is consistent with previous data.

The hierarchical model resulted in very little change of the patient-level coefficients from the standard logistic regression model. None of the independent variables changed with respect to the direction of their association with mortality. In the hierarchical model, when annualized hospital volume was entered into the analysis as a continuous variable, it was significantly associated with risk-adjusted mortality (coefficient of -0.0007, odds ratio of 0.9994, and p-value of 0.0026 for every additional patient). For example, for a hospital with state average volume per year (n=251), adding 100 more CABG procedures would reduce the in-hospital mortality rate by 0.08%.

The expected number of deaths at each hospital was calculated by summing the probabilities of death for all patients at each hospital, using the hierarchical model. The observed-to-expected (O/E) ratios were then plotted against annualized volume for the three years of data. These plots are shown in Figure 4. Each dot in the figure identifies a single hospital. The mean O/E ratio computed using the hierarchical logistic regression model was 1.021, with a range of 0.426 to 1.512. Figure 4 reveals that higher volume CABG hospitals tend to cluster around an O/E of 1.0, with less variation in performance as compared to hospitals with annual volumes below 200, where there is significant variation in performance results. Further, Figure 4 demonstrates that not all low volume hospitals have higher severity-adjusted mortality rates, and in fact, some low volume hospitals have very low severity-adjusted mortality rates.

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<sup>7</sup> Six hospitals submitted data for at least one complete year but did not want their results published.

**Figure 4: Plot of Observed to Expected (O/E) Ratio Versus Annualized Hospital Volume Using Results from the Hierarchical Logistic Regression Model**

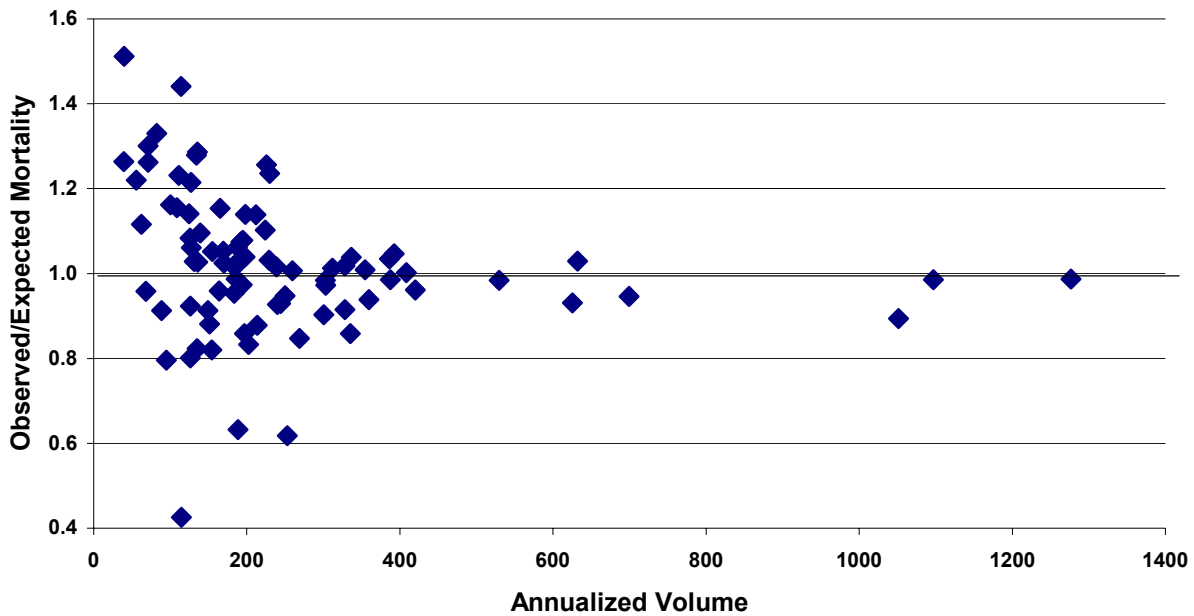


Table 6 presents the summary statistics when hospital volume was categorized into quartiles (<200, 200-299, 300-599, >=600) and dichotomized (>=450 and <450; and >=250 and <250). The quartiles were chosen because these volumes were used in the previous CCMRP report and because these cut-points split the data into four groups with a similar numbers of cases in each group. The split point of 450 procedures per year was chosen because of current recommendations by The Leapfrog Group ([www.leapfroggroup.org](http://www.leapfroggroup.org)). Again, the data show that patients face a reduced risk of dying from a CABG procedure in hospitals with higher annual volumes of CABG surgeries.

**Table 6: Hospital Volume Groups and Predicted Mortality Outcomes**

Volume Group	Hospitals (n=83) N (%)	Patients (n=57,387) N (%)	OR (95% CI)
>=600	6 (7)	16,145 (28)	0.56 (0.40, 0.79)
300-599	16 (19)	17,052 (30)	0.80 (0.63, 1.02)
200-299	14 (17)	8,168 (14)	0.74 (0.57, 0.97)
<200	47 (57)	16,022 (28)	Reference
>=450	7 (8)	17,734 (31)	0.65 (0.47, 0.89)
<450	76 (92)	39,653 (69)	Reference
>=250	26 (31)	35,286 (61)	0.73 (0.59, 0.89)
<250	57 (69)	22,101 (39)	Reference

What are the policy implications of these results? If, for example, all CABG patients went to hospitals with an annual volume of  $\geq 250$  cases, an overall reduction in predicted mortality of 0.51% would result. In other words, assuming 25,000 CABG procedures are conducted each year, 50 lives would be saved annually. If all CABG patients went to hospitals in the  $\geq 450$  volume group, a reduction in predicted mortality of 0.64% would result, or 110 lives saved annually. These projections assume that the higher-volume hospitals would continue to perform at their current standard of quality given increased volume.